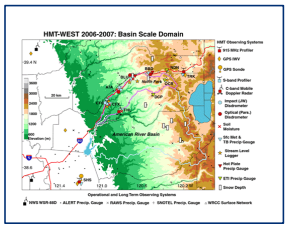
A QPE Product with Blended Gage Observations and High-Resolution WRF Ensemble Model Output: Comparison with Analyses and Verification during the HMT-ARB

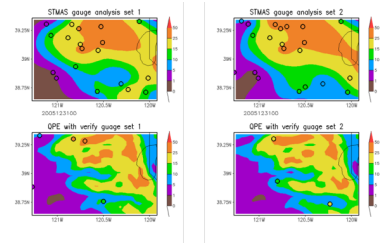
Edward I. Tollerud[1], John A. McGinley[1], Steven L. Mullen[2], Tomislava Vukicevic[3], Huiling Yuan[3], Chungu Lu[4], and Isidora Jankov[4]

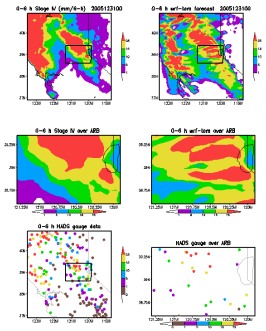
[1]*NOAA Earth System Research Laboratory (ESRL), Global Systems Division Boulder, Colorado USA* [2]*Department of Atmospheric Sciences, University of Arizona, Tucson, Arizona USA*
[3]*Cooperative Institute for Research in Environmental Sciences (CIRES), University of Colorado at Boulder, and Earth System Research Laboratory (ESRL), Global Systems Division, Boulder, Colorado*
[4]*Cooperative Institute for Research in the Atmosphere, Colorado State University, Fort Collins, Colorado USA, and Earth System Research Laboratory (ESRL), Global Systems Division, Boulder, Colorado USA*



1. Introduction

Particularly in regions of extreme terrain, timely quantitative precipitation estimates (QPE) during heavy rainfall/snowfall events are critical but difficult to obtain given instrumentation density and quality issues. For these situations, it is possible that a blend of short-term forecasts with observations might perform better than purely observational estimates. In this paper, we describe an example of this kind of system, one which applies variationally-driven ensemble methods to blend WRF forecasts with gage measurements. We apply them to a case of very heavy precipitation in the Northern California Sierra Nevada Mountains during December and January of 2005-6.





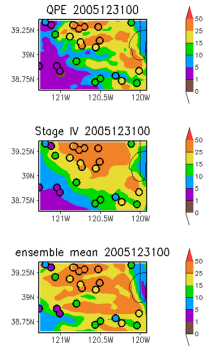
2. Domain, Methods, Observations, and Models

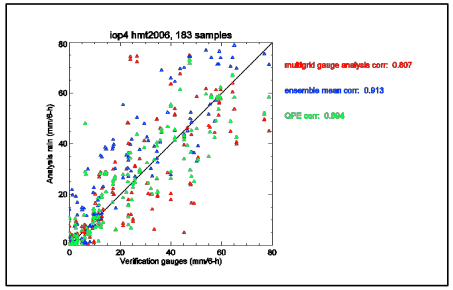
- Severe Terrain and orographic precipitation dominate over American River Basin
- IOP4 (12/31/2005-01/02/2006) produced most extreme precipitation during HMT1
- Mean and Covariance computed from solution to

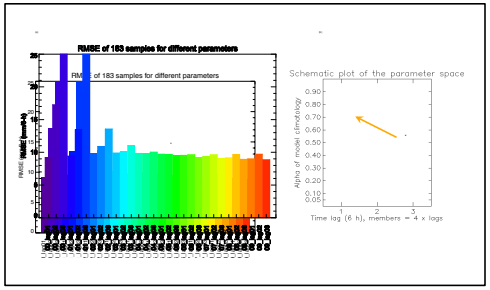
$$x_a = x_b + \left(HP_f H^T + R\right)^{-1} H^T R^{-1}(y - Hx_b)$$

$$P_a = (H^T R^{-1} H + P_f^{-1})^{-1}$$

- Background added to ensemble forecast members to ensure stability of solution
- Blended observations are HADS gage observations summed over 6h intervals
- 3-5 gage gages withheld from each ensemble member for verification purposes
- Time-lagged and multi-model (mixed microphysics) ensemble members (WRF)
- Quality of QPE depends on lag number and background ratio (alpha); (left below)
- Five runs with random withheld gages were made, giving ~183 verification pairs

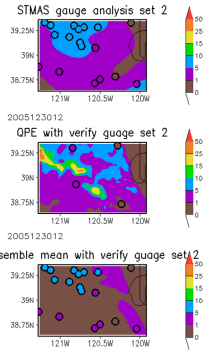


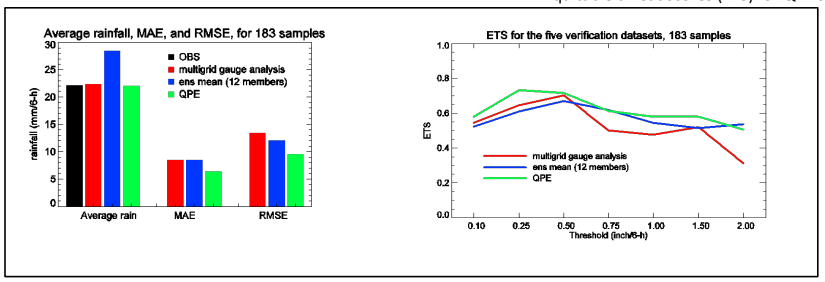




3. Results

- Stage IV analyses (panels directly above) smooth relative to ensemble mean forecast and blended product (QPE)
- QPE fields appear to retain finer model-scale terrain features , especially the east-west ridges (directly above)
- Randomized withholding of ~10% of gages has small effect on the QPE field patterns (far upper right panels)
- STMAS gage-only analyses suffer in regions of scarce or missing gage observations (Lake Tahoe; far upper right)
- Poor forecast timing in scenarios of general light precipitation result in spurious extreme rainfall maxima (right panels)
- Ensemble mean forecast scatter points cluster above 1:1 line on scatter plot, indicating a tendency to over-forecast
- STMAS correlation coefficients are below those of QPE and those of ensemble mean model forecasts
- Domain-averaged rainfall greatest for ensemble mean, indicating strong over-forecast (lower left color bar plots)
- Both QPE and STMAS provide unbiased estimates as compared gage observations (lower left color bar plots)
- Mean absolute errors (MAE) for STMAS and ensemble forecasts are similar; QPE values of MAE are ~25% better
- RMSE values for QPE are superior to both those of the ensemble mean and gage-only analyses (STMAS in this case)
- Equitable threat scores (ETS) for QPE superior to STMAS gage only analysis and ensemble mean (directly below)





4. Conclusions and Further Research

- Blended model/observation QPE fields verify favorably compared to observation-only analyses (STMAS)
- The inclusion of short-period model fields helps to capture model physics and terrain effects
- Sensitivity studies needed to test performance in other storms and for other precipitation scenarios
- Rigorous comparison with other methods to produce QPE fields is needed
- Improvements to computational efficiency (to avoid matrix inversion) are possible
- Impact of observational error estimates and number of lagged ensemble members should be done
- Extensions to input observations could include gridded precipitation estimates from radar and satellite
- Possible applications include techniques to define 'optimum' geographical distributions of rain gages
- Plans are being developed to apply the technique to land-falling hurricanes during the HMT-SE